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Description

[PROCESS FOR CREATING PHASE EDGE STRUCTURES]

Background of Invention

[0001] Field of the Invention

[0002] The present invention generally relates to a process which can reduce the complexity of the design and processing required to fabricate a phase edge on an alternating phase-shift photomask.

[0003] Description of the Related Art

[0004] As features being patterned using optical masks are reduced in size below the wavelengths of light, the optical masks have been designed with compensating features such as phase shift regions. These types of masks are often referred to as phase shift masks. There are many methodologies used to create such masks and an improved methodology is discussed below.

Summary of Invention

[0005] The invention provides a method of forming a phase shift mask that begins by forming an opaque chrome layer (mask) on a transparent quartz substrate. The invention performs a first patterning of the opaque chrome layer to expose a first region of the transparent quartz substrate and then etches the first region of the transparent quartz substrate through the chrome layer to create a phase shift region within the transparent quartz substrate. Next, the invention performs additional patterning of the opaque chrome layer to expose a second region of the transparent quartz substrate that is adjacent the first region. This additional patterning process enlarges the opening formed in the opaque mask in the first patterning process. The first region and the second region can comprise a continuous area of the transparent quartz substrate. The first region can comprise a rectangle, and the second region can comprise a similarly shaped and sized rectangle as the first region.

[0006] The process here is beneficial because it eliminates levels of processing, as well as reduces the complexity of processing. The fact that less lithography levels are required immediately reduces the number of design levels (design complexity, data volume, etc.). Reduction in lithography

levels also reduces the process complexity, and length (i.e., better yields, and TAT). With the invention, the overlay requirements for each level also become less stringent, which improves yield, and TAT.

[0007] These, and other, aspects and objects of the present invention will be better appreciated and understood when considered in conjunction with the following description and the accompanying drawings. It should be understood, however, that the following description, while indicating preferred embodiments of the present invention and numerous specific details thereof, is given by way of illustration and not of limitation. Many changes and modifications may be made within the scope of the present invention without departing from the spirit thereof, and the invention includes all such modifications.

Brief Description of Drawings

[0008] The invention will be better understood from the following detailed description with reference to the drawings, in which:

[0009] Figures 1A and 1B are schematic top-view and cross-sectional view diagrams of an optical mask;

[0010] Figures 2A and 2B are schematic top-view and cross-sectional view diagrams of an optical mask;

[0011] Figures 3A and 3B are schematic top-view and cross-sectional view diagrams of an optical mask;

[0012] Figures 4A and 4B are schematic top-view and cross-sectional view diagrams of an optical mask;

[0013] Figures 5A and 5B are schematic top-view and cross-sectional view diagrams of an optical mask;

[0014] Figures 6A and 6B are schematic top-view and cross-sectional view diagrams of an optical mask;

[0015] Figures 7A and 7B are schematic top-view and cross-sectional view diagrams of an optical mask; and

[0016] Figure 8 is a flow diagram illustrating a preferred method of the invention.

DETAILED DESCRIPTION

[0017] The present invention and the various features and advantageous details thereof are explained more fully with reference to the nonlimiting embodiments that are illustrated in the accompanying drawings and detailed in the following description. It should be noted that the features illustrated in the drawings are not necessarily drawn to scale. Descriptions of well-known components and processing techniques are omitted so as to not unnecessarily obscure the present invention. The examples used herein are intended merely to facilitate an understanding of ways

in which the invention may be practiced and to further enable those of skill in the art to practice the invention. Accordingly, the examples should not be construed as limiting the scope of the invention.

[0018] Figures 1A-3B illustrate a methodology that is utilized to create a phase shift mask. This methodology is not necessarily well known; however, the invention is an improvement on this methodology. More specifically, Figure 1A illustrates a top view of a patterned opaque layer 112 (e.g., chrome) over a transparent substrate 110 (e.g., quartz). Figure 1B illustrates the same structure in cross-sectional view along line X-X'. The pattern includes two openings 100, 102 in the opaque material 112 that are separated by a narrow region of opaque material 106. While only two openings are shown in the patterned opaque mask, one ordinarily skilled in the art would understand that the mask would normally include many more openings representing design features, and that the drawings used herein are substantially simplified to allow the salient features of the invention to be clearly recognized.

[0019] In Figures 2A-2B, which again are top and cross-sectional views (drawn along line X-X'), a mask 104 is patterned to protect one of the openings 100. The other opening 102

is then etched to create a recess in the transparent substrate 110. The mask is subsequently removed, as shown in Figures 3A-3B, and the separating portion of opaque material 106 is also removed (using a number of different methods such as additional masking an etching, etc.). This produces a larger opening (openings 100, 102 combined) that has a phase shift feature where light passing through portion 100 the shifted 180 degrees from the light passing through portion 102.

[0020] This process shown in Figures 1A-3B involves a number of masking, patterning, photolithographic, etching, etc. techniques. The invention shown in Figures 4A-6B substantially simplifies the process to produce the same structure. As with previous drawings, Figures 4A-6A are top views and Figures 4B-6B are cross-sectional views drawn along line X-X'. As shown in Figures 4A and 4B, the invention performs a first patterning of the opaque layer 112 to expose a first region 114 of the transparent substrate 110. The invention then etches the first region 114 of the transparent substrate 110 through the opaque layer 112 to create a phase shift region within the transparent substrate 110, as shown in Figures 4A and 4B. Next, the invention performs additional patterning of the opaque

layer 112 to expose a second region 116 of the transparent substrate 110 that is adjacent (contiguous with) the first region 114 using any well-known mask 108 and material removal process, as shown in Figures 5A and 5B. This additional patterning process enlarges the opening 114, 116 formed in the first patterning process. The mask is then removed as shown in Figures 6A and 6B.

[0021] The first region 114 and the second region 116 comprise a continuous area 114, 116 of the transparent substrate. In this example, the first region 114 comprises a rectangle and the second region 116 comprises a similarly shaped and sized rectangle as the first region; however, one ordinarily skilled in the art would understand that these openings can have any shape and can be different shapes. In addition, as discussed above, while only a limited number of openings are shown in the patterned opaque mask, one ordinarily skilled in the art would understand that the mask would normally include many more openings representing design features, and that the drawings used herein are substantially simplified to allow the salient features of the invention to be clearly recognized.

[0022] Figures 7A-7B are similar to Figures 6A-6B; however Figures 7A-7B illustrate additional regions 118 that are fea-

tures patterned into the opaque mask. These additional features 118 are contrasted with features 114, 116 in that features 118 do not include phase shift components. Therefore, the invention can be used to form a number of different types of masks, including those with phase shift features only in some regions of the mask.

[0023] Figure 8 shows the processing of the invention in flowchart form. More particularly, in item 800, the invention performs a first patterning of the opaque chrome layer to expose a first region of the transparent quartz substrate. In item 802, the invention etches the first region of the transparent quartz substrate through the chrome layer to create a phase shift region within the transparent quartz substrate. Next, the invention performs additional patterning of the opaque chrome layer to expose a second region of the transparent quartz substrate that is adjacent the first region 804. This additional patterning process enlarges the opening formed in the first patterning process. The processing here is beneficial for a number of different reasons. In one example, the invention eliminates various levels of processing, and reduces the complexity of that processing. The fact that less lithographic levels are required immediately reduces the

number of design levels (design complexity, data volume, etc.). Reduction in lithographic processing levels also reduces the process complexity, and length (i.e., yield, TAT, capacity, defects, RPT). With the invention, the overlay requirements for each level also become less stringent, which improves yield, and TAT.

[0024] With the invention, the etch process window and capability are improved because the resist is removed from the etch system. Etching without resist reduces ARDE (Aspect Ratio Dependent Etching), and any chemistry effects the resist may add to the etch system.

[0025] Overlay requirements are relaxed with the invention because in the original method, the second level lithography process had to land on the opaque region between the two clear openings (112). However, in the second process, the second lithography process only has to hit the large opening (which provides more room for error).

[0026] While the invention has been described in terms of preferred embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the appended claims.